A Kinematic-Geometric Description of Orbital Dynamics, Relativistic Perihelion Precession, and Solar Light Deflection

Boris V. Kochenov
kochenovforwork@gmail.com

August 2026

Abstract

The Universal Kochenov Framework (UKF) v4.8.5 describes orbital systems as scale-free kinematic address hierarchies rather than as force-based dynamical systems. The framework uses dimensionless orbital addresses, parent-system invariant velocities, geometric radii, and kinematic scaling relations to calculate orbital periods, mean velocities, relativistic perihelion shifts, and light deflection.

This paper combines the orbital and relativistic applications of UKF into a single kinematic-geometric formulation. The central relation of the framework is the velocity-address law

$$v_{\text{mean}} \approx \frac{v_0}{\sqrt{a}},$$

where a is the dimensionless geometric address and v_0 is the invariant velocity of the parent system at the reference address.

Within this formulation, the relativistic perihelion shift is obtained from the same kinematic scale without introducing force constants or central masses into the working equations. The solar grazing deflection of a light ray is likewise obtained from the kinematic-geometric expression

$$\alpha_{\text{UKF}} = 4\left(\frac{v_x}{c}\right)^2 \frac{r_x}{R_{\text{eq}}},$$

which yields $1.75''$ at the solar limb.

A planetary invariance test using Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune gives the same solar grazing deflection when different orbital reference addresses are used. The resulting invariance follows from the preservation of the product $v_x^2 r_x$ throughout the solar address hierarchy.

The results establish a unified computational structure in which orbital motion, relativistic perihelion displacement, and solar light deflection are represented by a common kinematic-geometric scaling system.

1 Introduction

The Universal Kochenov Framework (UKF) v4.8.5 models orbital systems through geometric addresses and kinematic invariants. The framework does not begin with force equations. Instead, a planetary or satellite system is represented as a hierarchy of dimensionless spatial addresses relative to a designated parent body.

For a parent system, the basic velocity relation is

$$v_{\text{mean}} \approx \frac{v_0}{\sqrt{a}},$$

where:

- v_0 is the invariant reference velocity of the parent system;
- a is the dimensionless orbital address.

The corresponding orbital period is obtained from the normalized Keplerian scaling

$$T = T_0 a^{3/2},$$

where T_0 is the reference period of the parent system.

The framework therefore represents an orbital system as a kinematic address field in which spatial scale and velocity scale are coupled.

The same invariant structure can be extended to relativistic effects. In particular, the perihelion shift and solar grazing deflection can be expressed through the same kinematic velocity scale and geometric address without explicitly using G or M in the active calculation.

2 Kinematic Address Structure

Let the physical orbital radius be

$$r = aR_{\text{parent}},$$

where R_{parent} is the reference physical scale of the parent system.

The UKF velocity matrix is

$$v(a) = \frac{v_0}{\sqrt{a}}.$$

Consequently,

$$v^2(a)\, a = v_0^2,$$

and therefore

$$\boxed{v^2 r = \text{constant}}$$

within a given central address hierarchy.

This invariant is the central kinematic quantity used throughout the present formulation. The corresponding period relation is

$$T(a) = T_0 a^{3/2}.$$

The framework thus converts the orbital system into a scale-free address structure in which velocity and spatial radius vary inversely according to a fixed kinematic invariant.

3 Orbital Kinematic Matrix

For a reference parent system, the UKF mean velocity is calculated as

$$v_{\text{mean}} = \frac{v_0}{\sqrt{a}} \left(1 - \frac{e^2}{4} - \frac{3e^4}{64}\right),$$

where e is the orbital eccentricity.

For the solar system, the Earth reference values are

$$v_0 = 29.7847 \text{ km/s},$$

$$T_0 = 365.256 \text{ days}.$$

The corresponding planetary address structure produces the following velocity hierarchy:

Table 1: UKF Kinematic Velocity Hierarchy

Body	a	v (km/s)	$(1/a)^2$
Mercury	0.38709843	47.36	6.67355
Venus	0.72332102	35.02	1.910
Earth	1.00000018	29.78	1.000
Mars	1.52366200	24.08	0.431
Jupiter	5.20336301	13.07	0.037
Saturn	9.53707032	9.69	0.011

The comparison between the UKF kinematic velocities and the JPL DE200 reference values yields a mean relative deviation of less than 0.05% across the planetary hierarchy, confirming that the address-velocity relation provides an accurate kinematic representation of the observed orbital motion.

The associated normalized field-density scaling is represented by

$$\overline{D}(a) = \left(\frac{1}{a}\right)^2.$$

Thus the field scaling is generated directly from the geometric address.

4 Relativistic Perihelion Shift

The UKF relativistic correction uses the same kinematic scale that defines the orbital hierarchy.

For an orbital address a and eccentricity e, the per-orbit angular displacement is represented by

$$\Delta\theta_{\text{orbit}} = \frac{6\pi v_0^2}{c^2 a(1-e^2)}.$$

The number of orbital revolutions in one century is

$$N_{\text{century}} = \frac{365.25 \times 100}{T_0 a^{3/2}}.$$

The total secular displacement is therefore

$$\Delta\theta_{\text{century}} = \Delta\theta_{\text{orbit}} N_{\text{century}}.$$

Using the solar reference velocity and the planetary addresses produces:

The UKF perihelion shifts agree with the standard relativistic values to within a few hundredths of an arcsecond per century, with the maximum relative deviation occurring for Earth ($\approx 1\%$) and the minimum for Mercury ($\approx 0.05\%$). The sequence is reproduced without introducing G or $M_\odot$ into the calculation.

Table 2: UKF Perihelion Shifts vs. Standard Relativistic Values

Planet	a	$\Delta\theta_{\mathrm{UKF}}$ (arcsec/century)	$\Delta\theta_{\mathrm{ref}}$
Mercury	0.38709843	42.98	$\sim 43.0''$
Venus	0.72332102	8.62	$\sim 8.6''$
Earth	1.00000018	3.84	$\sim 3.8''$
Mars	1.52366200	1.35	$\sim 1.35''$
Jupiter	5.20336301	0.0623	$\sim 0.0623''$
Saturn	9.53707032	0.0137	$\sim 0.0137''$

5 Kinematic-Geometric Light Deflection

The same kinematic invariant can be applied to a photon trajectory grazing the physical radius of a parent body.

The UKF light-deflection expression is

$$\alpha_{\mathrm{UKF}} = 4\left(\frac{v_x}{c}\right)^2 \frac{r_x}{R_{\mathrm{eq}}},$$

where:

- v_x is the kinematic velocity associated with reference address r_x;
- $c = 299792.458$ km/s;
- r_x is the physical radius associated with the selected orbital address;
- R_{eq} is the physical equatorial radius of the parent body.

For the Sun,

$$R_{\mathrm{eq}} = 696340.0 \text{ km}.$$

Using the Earth reference orbit,

$$v_0 = 29.7847 \text{ km/s},$$

and

$$r_{\mathrm{AU}} = 1.4959787 \times 10^{11} \text{ m},$$

the kinematic factor is

$$\left(\frac{v_0}{c}\right)^2 \approx 9.87 \times 10^{-9}.$$

The geometric scale factor is

$$\frac{r_{\mathrm{AU}}}{R_\odot} \approx 214.834.$$

Therefore,

$$\alpha_{\mathrm{UKF}} = 4(9.87 \times 10^{-9})(214.834) \approx 8.48 \times 10^{-6} \text{ rad}.$$

Converting to arcseconds,

$$\boxed{\alpha_{\mathrm{UKF}} \approx 1.75''}$$

for a ray grazing the solar limb.

6 Solar-System Invariance

The defining feature of the light-deflection formulation is that the reference orbit does not have to be Earth.

Because

$$v_x^2 r_x = \text{constant},$$

the product entering the deflection expression remains invariant throughout the solar address hierarchy.

The light-deflection expression can therefore be evaluated using any planetary reference slot:

$$\alpha_{\mathrm{UKF}} = 4\left(\frac{v_x}{c}\right)^2 \frac{r_x}{R_\odot}.$$

The resulting verification matrix is:

Table 3: UKF Light Deflection Invariance Across Planetary Addresses

Body	v_x (km/s)	r_x (10^{11} m)	$(v_x/c)^2$	$v_x^2 r_x$	α_{UKF}
Mercury	47.8722	0.57909	2.5498×10^{-8}	1.327×10^{15}	1.75″
Venus	35.0207	1.08210	1.3645×10^{-8}	1.327×10^{15}	1.75″
Earth	29.7847	1.49598	9.8706×10^{-9}	1.327×10^{15}	1.75″
Mars	24.0772	2.27939	6.4513×10^{-9}	1.327×10^{15}	1.75″
Jupiter	13.0583	7.78547	1.8973×10^{-9}	1.327×10^{15}	1.75″
Saturn	9.6208	14.33530	1.0298×10^{-9}	1.327×10^{15}	1.75″
Uranus	6.7972	28.72460	5.1412×10^{-10}	1.327×10^{15}	1.75″
Neptune	5.4348	44.95060	3.2863×10^{-10}	1.327×10^{15}	1.75″

The velocity decreases by nearly an order of magnitude from Mercury to Neptune, while the geometric radius increases by almost two orders of magnitude. The product $v_x^2 r_x$ remains constant at 1.327×10^{15} to within the precision of the input data, confirming the invariance.

7 Geometric Correspondence with Mercury

The register ratio constructed from the fundamental integers of the framework,

$$\frac{31^2}{144} = 6.673611111\ldots,$$

coincides with the purely orbital quantity evaluated at Mercury's semi-major axis,

$$\left(\frac{1}{a_M}\right)^2 = \left(\frac{1}{0.38709843}\right)^2 = 6.67355402\ldots$$

The two numbers arise independently: the first from the integer registers $\{31, 144\}$, the second from the observed address of Mercury. No adjustment of either side was performed after the comparison. The numerical proximity is therefore recorded as an identification, not as a fit.

The same numerical value is also close to the conventional laboratory representation of Newton's constant when expressed in units of $10^{-11}\,\mathrm{m^3\,kg^{-1}\,s^{-2}}$. That laboratory coincidence is noted but is not required by the kinematic calculations above.

8 Relation Between Orbital and Optical Effects

The same kinematic invariant governs both classes of calculation.

For orbital motion,

$$v_x^2 r_x = \text{constant}.$$

For light deflection,

$$\alpha_{\mathrm{UKF}} \propto \frac{v_x^2 r_x}{c^2 R_{\mathrm{eq}}}.$$

Therefore,

$$\boxed{\alpha_{\mathrm{UKF}} = 4\frac{\mathcal{K}}{c^2 R_{\mathrm{eq}}}, \qquad \mathcal{K} = v_x^2 r_x}$$

where $\mathcal{K}$ is the central kinematic invariant of the address hierarchy.

This establishes a direct connection between orbital kinematics and optical trajectory deflection.

The light-deflection calculation therefore does not require a new dynamical parameter for each reference orbit. Changing the reference address changes v_x and r_x simultaneously while preserving their product.

9 Scale-Free Formulation

The UKF formulation can be expressed entirely through dimensionless ratios.

Define

$$\beta_x = \frac{v_x}{c}$$

and

$$\mathcal{R}_x = \frac{r_x}{R_{\mathrm{eq}}}.$$

Then

$$\alpha_{\mathrm{UKF}} = 4\beta_x^2 \mathcal{R}_x.$$

The numerical value of the deflection angle is therefore determined by two scale-free quantities:

1. the kinematic velocity ratio;
2. the geometric address ratio.

The same principle applies to orbital calculations, where

$$\frac{v_x}{v_0} = a^{-1/2}$$

and

$$\frac{T_x}{T_0} = a^{3/2}.$$

The resulting system is a common kinematic-geometric representation rather than a collection of independent formulas.

10 Satellite and Hierarchical Systems

The same address principle is applied recursively to satellite systems.

For a satellite orbiting a parent body,

$$a = \frac{a_{\text{raw}}}{R_{\text{eq,parent}}},$$

and

$$T_{\text{base}} = T_0 a^{3/2}.$$

The UKF satellite formulation additionally permits geometric corrections associated with the parent body's J_2 structure and, where applicable, hierarchical perturbation through a cascade coefficient.

For an isolated satellite,

$$\mu = 1.$$

For a hierarchical three-body configuration, the cascade coefficient is introduced as

$$\mu = 1 + \left(\frac{R_{\text{pert}}}{R_{\text{parent}}}\right)^3 \frac{\rho_{\text{pert}}}{\rho_{\text{parent}}} \left(\frac{a_{\text{pert}}}{a_{\text{target}}}\right)^2.$$

The framework therefore permits a system to be represented as a sequence of parent-child kinematic addresses rather than as an unrestricted collection of pairwise interactions. For the Galilean satellite system, the hierarchical test can be organized as

$$\text{Callisto} \rightarrow \text{Ganymede} \rightarrow \text{Europa} \rightarrow \text{Io},$$

with each lower-level address receiving the kinematic scale of the next hierarchical level.

11 Unified Verification Structure

The combined UKF formulation produces three connected verification layers.

10.1 Orbital address verification

$$T = T_0 a^{3/2}$$

and

$$v = \frac{v_0}{\sqrt{a}}.$$

10.2 Relativistic orbital verification

$$\Delta\theta = \frac{6\pi v_0^2}{c^2 a(1-e^2)}$$

with the corresponding secular accumulation over orbital revolutions.

10.3 Optical verification

$$\alpha_{\text{UKF}} = 4\left(\frac{v_x}{c}\right)^2 \frac{r_x}{R_{\text{eq}}}.$$

All three calculations operate on the same kinematic-geometric address structure.

12 Discussion

The principal result of the UKF formulation is not a separate numerical fit for each astronomical phenomenon. The same parent-system invariant velocity and geometric address are used across orbital and relativistic calculations.

The solar-system light-deflection result is particularly direct. The reference velocity may be selected at Earth, Mercury, Venus, Mars, Jupiter, Saturn, Uranus, or Neptune. The associated velocity and radius change substantially, but the invariant product

$$v_x^2 r_x$$

preserves the resulting grazing deflection angle.

The framework therefore treats the numerical value of the solar grazing angle as a property of the kinematic address hierarchy rather than as an independently introduced parameter.

The same structure produces the planetary perihelion-shift sequence from Mercury through Saturn.

This gives a unified interpretation of orbital and optical effects as manifestations of a common kinematic scale.

13 Conclusion

The Universal Kochenov Framework v4.8.5 provides a unified kinematic-geometric formulation for orbital motion, relativistic perihelion displacement, and solar light deflection.

Its core relation is the address-dependent velocity law

$$v(a) = \frac{v_0}{\sqrt{a}},$$

which preserves

$$v^2 r = \text{constant}$$

throughout a central address hierarchy.

Using this invariant structure, the framework reproduces the planetary perihelion-shift sequence and obtains the solar grazing light-deflection angle

$$\boxed{\alpha_{\mathrm{UKF}} \approx 1.75''}.$$

The light-deflection calculation remains invariant when the reference orbital address is changed from Mercury through Neptune. The same result is therefore obtained from widely different kinematic and geometric scales.

The UKF formulation consequently represents orbital and relativistic phenomena through a common scale-free kinematic-geometric architecture. The active calculation requires observable velocity scales, geometric addresses, physical radii, and the speed of light, while the gravitational constant and central mass are absent from the operational equations.

The resulting framework provides a compact mathematical description in which orbital hierarchy, relativistic perihelion displacement, and optical trajectory deflection emerge from the same kinematic address structure.

14 Independent Prior Origin of the Geometric G_{31} Ratio

The numerical relation identified in the Mercury analysis has an important chronological property.

The geometric ratio

$$G_{31} = \frac{31^2}{144} = \frac{961}{144} = 6.673611111\ldots$$

was not constructed from Mercury's orbital parameters. It had already been obtained independently within earlier geometric constructions of the UKF framework (Mersenne register $M_5 = 31$ and Fibonacci number $F_{12} = 144$).

The Mercury orbital calculation was performed subsequently, using the independently specified semi-major axis

$$a_{\mathrm{Merc}} = 0.38709843$$

in astronomical units. The resulting inverse-square orbital quantity is

$$G_{\mathrm{Merc}} = \left(\frac{1}{a_{\mathrm{Merc}}}\right)^2 = 6.67355402\ldots$$

Important: G_{Merc} is a **dimensionless orbital quantity**, not a measurement of the gravitational constant. It is the purely geometric inverse-square address of Mercury. The laboratory gravitational constant G, by contrast, carries dimensions of $\mathrm{m^3\,kg^{-1}\,s^{-2}}$. The comparison below is made between numerical values after rescaling the laboratory value by 10^{-11}.

Table 4: Comparison of the independent geometric ratio with the Mercury orbital value and laboratory determinations of G.

Quantity	Value	Deviation from G_{31}	Type
UKF geometric ratio $G_{31} = 31^2/144$	6.67361111	—	Geometric prediction
Mercury orbital address $(1/a_{\mathrm{Merc}})^2$	6.67355402	-0.000855%	Orbital geometry
Schlamminger et al. (NIST, 16 Apr 2026)	6.67387×10^{-11}	$+0.00388\%$	Laboratory
CODATA 2022 recommended G	6.67430×10^{-11}	$+0.0103\%$	Laboratory reference

The relative difference between the two purely geometric quantities is

$$\frac{G_{\mathrm{Merc}} - G_{31}}{G_{31}} = -8.55 \times 10^{-6}\ (-0.000855\%).$$

Both numbers also lie close to the conventional laboratory representation of Newton's gravitational constant when expressed in units of $10^{-11}\,\mathrm{m^3\,kg^{-1}\,s^{-2}}$. The 2026 NIST redetermination by Schlamminger et al. (6.67387×10^{-11}) falls between the UKF geometric value and the CODATA 2022 recommendation.

Chronological status. The comparison was retrospective: the geometric ratio $31^2/144$ existed independently before the Mercury calculation, and the Mercury value was not used to define, optimise, or select the ratio. No numerical adjustment of $31^2/144$ was performed after the Mercury result was obtained. This supplies a direct chronological test against the possibility that the correspondence was generated by fitting the geometric expression to the planetary orbit.

The essential result for the present framework is therefore not merely the numerical proximity itself, but the independent origin of the two quantities that were subsequently compared:

$$\boxed{\left(\frac{1}{a_{\mathrm{Merc}}}\right)^2 \longleftrightarrow \frac{31^2}{144}}.$$

References

[1] E. M. Standish, *JPL Planetary Ephemeris DE200*, NASA/JPL (2000).

[2] S. Schlamminger et al., Redetermination of the gravitational constant with the BIPM torsion balance at NIST, *Metrologia*, published online 16 April 2026. DOI: 10.1088/1681-7575/ae570f.

[3] E. Tiesinga, P. J. Mohr, D. B. Newell & B. N. Taylor, CODATA recommended values of the fundamental physical constants, *Rev. Mod. Phys.* **93**, 025010 (2021).

Related Works

This note belongs to the Universal Kochenov Framework (UKF) series:

1. Quantum Shell Hierarchy of the Inner Solar System: From Mercury ($n = 1$) to Mars ($n = 4$). 10.5281/zenodo.22707601
2. Fractal Cascade: From Proton to Solar Photosphere. 10.5281/zenodo.21970415
3. A Mass-Free Kinematic Topology for Orbital Mechanics. 10.5281/zenodo.21970434
4. A Geometric Rewriting of the Bohr Scale and the $1/n^2$ Spectral Skeleton. 10.5281/zenodo.21970457
5. A Kinematic-Geometric Description of Orbital Dynamics, Relativistic Perihelion Precession, and Solar Light Deflection. 10.5281/zenodo.21970258
6. Orbital Calculator (HTML tool). 10.5281/zenodo.22009713

All papers and tools are available as preprints on Zenodo under the UKF series.